Boiling Point: How Gradual Heat Change Escapes Our Perception

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Table of Contents

Introduction

Hypothesis

The hypothesis for this project and experiment is that if we gradually change the temperature in a room over a certain time, then the average person should feel no difference as their body becomes tolerant. This is because our bodies' thermoreceptors will gradually adapt to external heat. This hypothesis intends to address why environmental activism has become stagnant as time passes and the effects of temperature tolerance on the human perspective.

Project Background

Gradual changes in stimuli often evade human perception, a phenomenon that impacts human safety, behavior, and understanding of the world. This project investigates how a gradual increase in temperature calls attention to the tendency of society to overlook changes that become imperceptible over time. However, rather than becoming aware of steady increases in graphs and the extinction of species, we are hoping to provide a different approach to climate change awareness and activism. For example, if an individual is asked if they know climate change exists, many will respond yes but still choose to make choices that negatively affect the environment. Humans wait for immediate and noticeable emergencies before taking action, and by then, it is often too late. To demonstrate this phenomenon, an experiment with ~30 participants has been conducted, and a bar graph has been created to showcase the results. Many will agree that climate change is a pervasive issue. However, many do not understand why no action is being taken. We would like to illustrate to society the biological tendencies to avoid and ignore in the hopes of instigating tangible change.

During our experiment, ambient room conditions were altered to see participants becoming tolerant to the changing environment. In the course of half an hour, three changes occurred: light, sound, and temperature. Our project focuses on temperature, but other stimuli were modified to prevent the placebo effect of knowing the temperature will change. Participants were also given tasks and mind games to complete to divert attention away from the purpose of the experiment. Afterward, we handed out a form for participants to fill out and mark what gradual change they had noticed. Many had noticed the room's brightness being lowered gradually. However, only 12.9% marked temperature as a changed variable.

Purpose of our Experiment

Global changes occur gradually over time, reducing the immediate urgency to act and allowing the body to adapt to new conditions. Knowing an issue exists is not enough to encourage change in the status quo. Rather, understanding how easy it is to ignore is what needs to be prioritized. While society is aware of this change and its effects on ecosystems and daily life, many individuals may not recognize its impact. When asked about how global warming has specifically affected them, many people report little noticeable difference. This phenomenon is often discussed in reports on climate change, but it's important to emphasize that even if it seems like our typical lifestyle is unaffected, the temperature has an impact. Whether it's the strain on our bodies to maintain a healthy temperature or the increased need for water due to increased sweating, the effects of rising temperatures are influencing us in ways we may not immediately recognize. This experiment will draw a connection between the gradual nature of climate change and the impacting effects of our body’s trying to regulate itself.

Research Data

Global Warming

Global warming occurs because of many factors, though occasionally natural, it usually stems from the actions of the human species. During the burning of fossil fuels, the production of general goods, deforestation, agriculture, etc, greenhouse gases are released into the atmosphere. Greenhouse gases (GHG) come in a variety of forms. CO2, CH4, N2O, and O3 are the most known examples, however, more chemicals are becoming excessive in our atmosphere, leading to many more affecting our ecosystems. These GHGs block UV rays from leaving the atmosphere. If UV rays are unable to exit, they are instead forced to warm up the Earth continuously. This process leads to rising sea levels due to melting ice sheets, forcing marine ecosystems to adapt to survive such conditions. Consequently, it also takes away from the arctic biome. Impacting flora and fauna that reside there, simultaneously releasing methane or CO2 patches in the ice. Also, the rise in sea level may impact and change the global converter belt, changing how heat circulates the globe and affecting every biome, ecosystem, etc. Since the industrial revolution, 37.15 $GtCO_2$ 2022 has been recorded to be released [38]. Overall, this led to a 1.1°C increase in the average atmospheric temperature. This has already led to many species leaving the optimum range. Most ecologists believe that biodiversity is disappearing at an alarming rate, with up to 150 species going extinct per day, according to scientists working with the United Nations Convention on Biological Diversity [19]. With these numbers, we can begin understanding the impact of releasing GHG into the atmosphere on the world.

Current Awareness Methods

Although some measures have been taken in Calgary to educate youth on climate change, many are ineffective or inefficient. Teachers in Alberta and students in Calgary are restless with the lack of resources and seemingly little government action.

An examination of Alberta's curriculum reveals many weaknesses. The provincial curriculum has been criticized for not adequately addressing climate change and the broader issues of sustainability. In a 2019 study by climate change researcher Seth Wynes, it was revealed that Alberta's education system lags behind other provinces in providing comprehensive climate education. The study noted that key topics such as "It's climate," "It's warming," and "It's us" were not mandatory components of Alberta's curriculum, despite being foundational to understanding the science of climate change. Additionally, the curriculum did not emphasize the urgency of climate action or the role of individual and collective responsibility in mitigating its effects [27]

Not only has Calgary's education system proven to be an unreliable form of environmental education, but current approaches to fearmonger youth into reducing waste and recycling by society are only causing desensitization. A study by Alexandra Alhadeff from the Yale School of the Environment examined how exposure to environmental degradation affects students' emotions, behaviors, and perceptions of their ability to make a difference. A total of 147 middle and high school students were randomly divided into experimental and control groups. Over four days, the experimental group watched videos showing environmental harm, while the control group watched neutral content. Surveys assessed emotional and attitudinal changes, and recycling behavior was observed using juice cartons. Results indicated that students exposed to environmental degradation felt more negative emotions compared to the control

group, especially younger participants. Middle school students showed increasingly negative emotions with each video, but high school students did not. By the third day, students in the experimental group were significantly less likely to recycle. Interviews revealed that participants felt powerless against environmental problems, leading to desensitization and a reduced likelihood of engaging in environmentally responsible behavior (ERB). Those with a stronger connection to nature felt more capable of making a difference. The study suggests that repeated exposure to environmental harm may lead to desensitization and decreased ERB.

In conclusion, while some measures have been taken in Calgary to educate youth about climate change, these efforts are insufficient given the urgency of the issue. Our experiment intends to file through possible reasons why current awareness methods are ineffective and how we can use knowledge of human psychology to increase activism.

Thermoreceptors

In mammals, thermoreceptors detect temperature through the nervous system. Thermoreceptors are specialized sensory receptors that detect temperature changes, enabling the body to perceive and respond to thermal stimuli. These sensory neurons give information to the central nervous system (CNS), while the motor neurons take information away from the CNS [16]. This process enables the human body to react to temperature, whether consciously or unconsciously. Physical reactions are unconscious but noticed by the individual almost immediately after they're completed. During a physical reaction, motor neurons in the body will tense the muscles in the arm, effectively removing itself from high sources of heat or something frozen. Most individuals know this and discreetly avoid extreme surfaces for this reason, but global warming has not increased the temperature to the point that such reactions occur. Instead

of the atmospheric temperature gradually influencing the weather, our body is adapting. We can feel the temperature in the air. However, the reaction is quite limited. Our motor neurons will not be informed to move away from the source, as there is no harm occurring. Our body instead recognizes the change and adapts its self-regulating process.

To reach homeostasis, any self-regulating process by which biological systems tend to maintain stability, there are many processes our body can complete [16]. An example of adapting to an increase in atmospheric temperature is sweat, decreasing the chance of overheating. In humans, sweating is the most powerful autonomic thermoregulator. The evaporation of sweat provides the greatest potential for heat loss and represents the most advanced method of heat loss when air temperature exceeds skin temperature [18]. When sweating, the synapse and neuroglandular junction located between the end of a motor nerve and muscle produces acetylcholine. Acetylcholine is a neurotransmitter that plays a role in memory, learning, attention, arousal, and involuntary muscle movement [8]. When this chemical compound is released, it binds to specific tissues in the central nervous system that stimulate eccrine glands to secrete sweat. When the eccrine glands produce this fluid, it sits on the skin, cooling the body through evaporation. Similarly, though not as regulating, is the process of vasodilatation. During vasodilatation, the blood vessels under the skin expand, increasing the blood flow to your skin. This lets the body release heat outwardly [1]. In a controlled system, both of these systems work simultaneously to prevent heat stroke. However, in recent times, with the increase of the atmosphere globally, these systems have become overused in an attempt to maintain a 36.5 ° C body temperature.

For the body to regulate its core temperature during an atmospheric decrease in temperature, there are two main methods. The first method is shivering. The muscles create

involuntary movements to decrease the amount of oxygen in said tissues. To reverse this process and reach equilibrium. The circulatory system sends an increased amount of blood filled with oxygen and, consequently, heat. The second method used more commonly is vasoconstriction. This process is the opposite of vasodilation, yet rather than expanding the blood vessels, they are narrowed [37]. This may seem counterintuitive; however, the heat produced by the cardiovascular system is now stored close to the body's inner body, increasing the body's core temperature. There are similar but less commonly used methods. An example is hormonal thermogenesis, where the thyroid releases a series of hormones. Typically, this increases metabolism, consequently increasing the energy your body must create. The increased energy production creates heat as a byproduct, regulating the body's core temperature. When talking about adaptability with these methods, vasodilation will occur unconsciously. Some symptoms, like cold limbs, may be common. However, the average person does not assume it is because of the body adapting. Instead of thinking it is a natural product of their body adapting to the atmospheric temperature, the individual assumes it is from a different cause.

Both have a resting discharge so that an appropriate change of skin temperature reduces the firing rate of one type as well as increasing the firing rate of the other. The methods, though useful in extreme cases like hypothermia and heat stroke, are not to be active consistently. If this happens, the body may begin experiencing problems like dehydration and loss of electrolytes from the constant use of sweat glands. Increased risk of infections as the body is producing and using more energy than typically recommended, making the autoimmune system weak. Increased chance of bacterial growth in many communities and on their buildings, animals, or skin. When regarding vasodilation and vasoconstriction, the blood vessel function can be impaired. Due to

the excessive use. All of this already proves how dangerous abrupt or gradual changes to the human body can be.

Tolerance

The processes involving these neurons occur without conscious awareness, meaning certain adaptations to temperature changes take place unconsciously. While humans can adapt to extreme dry heat with sweat, humid heat still poses a critical survival risk once sweating ceases to cool the body effectively. Heat stroke is a severe condition traditionally defined as a rectal temperature exceeding 40.6°C, accompanied by neurological symptoms. It results from significant cardiovascular strain combined with thermoregulatory failure. In such cases, the internal heat load overwhelms the body's capacity to maintain core temperature, forcing the system to prioritize arterial pressure and blood flow to vital organs over temperature regulation. The process is an unconscious reaction that increases the possibility of heat-caused diseases.

Past Experiments

Stimulus has been commonly experimented on and is typically used in correlation to Weber's Law. Weber’s Law states that when applying an increase to a certain stimulus, the increase must rise proportionally for it to be noticeable. The law was originally postulated to describe research on weight lifting by the German physiologist Ernst Heinrich Weber in 1834 and was later applied to the measurement of sensation by Weber’s student Gustav Theodor Fechner, who went on to develop from the law the science of psychophysics [14]. During the experiment on this law, many discoveries were made on stimulant reactions to steady increases in temperature. Weber's findings include the concept that humans can detect temperature differences as small as 2/5° R (equivalent to 0.5°C). There have been many incidents and reports

written on people's perceptions of temperature; an example is a famous experiment from 18th century London where Mr. Blagden, Secretary of the Royal Society of London, experimented by entering a room heated to 105°C with eggs, steak, and a dog. After 15 minutes, the eggs were baked, and the steak cooked, but Blagden and the dog remained unharmed. This demonstrated that humans can tolerate extreme dry heat if sweat can evaporate freely, hot surfaces are avoided, the circulatory system adapts, and exposure time is limited.

Survey/Interview Data

Experiment Process

There were two interactions in our experiment. Experiment 1 took place 2 days before experiment 2; the room temperature started at 23.3 degrees C. The noise had started at .5 Watts, and the lights at the lowest intensity. Experiment 2's room temperature started at 22.5 degrees C. While the noise also started at .5 Watts, the light had begun at the highest intensity. Both conductors begin by sitting down and explaining a brief note to the patients. The room conditions were to be changed over a thirty-minute session. The patients did not know what conditions were going to be changed. However, they may have guessed possible variables from past information on our research, warning labels, and easy-to-change variables. For our control variable, we changed the light settings in ten-minute increments. The lights were changed intensely to display that humans will notice the immediate change at a higher rate than a gradual increase. This was also done to confirm participants were filling out the form accurately and truthfully. As displayed in Fig 1, all participants noticed. Our next variable change was the noise level, which was increased in increments of 5 minutes by .5-.8 Watts. During both experiments, the speaker was placed to the right of the conductors, and it was evident that participants near the speaker noticed an increased percentage. Finally, our last variable altered was temperature, relating to global warming. During Experiment 1, the temperature started at 23.2, and at 15:45, it had adjusted to 23.6. At 15.53, observers noticed a change; however, as discussed in "Experimental Errors," this may have been due to other reasons. At 16:00, the temperature was recorded at 22.7 degrees C. Finally, at 4:15, the experiment concluded, and the temperature ended at 22.9 degrees C. This means a .7 degree C increase, and though it had not reached the full 1.1 degrees C, the global temperature has increased; it certainly was close. For experiment 2, the temperature started at

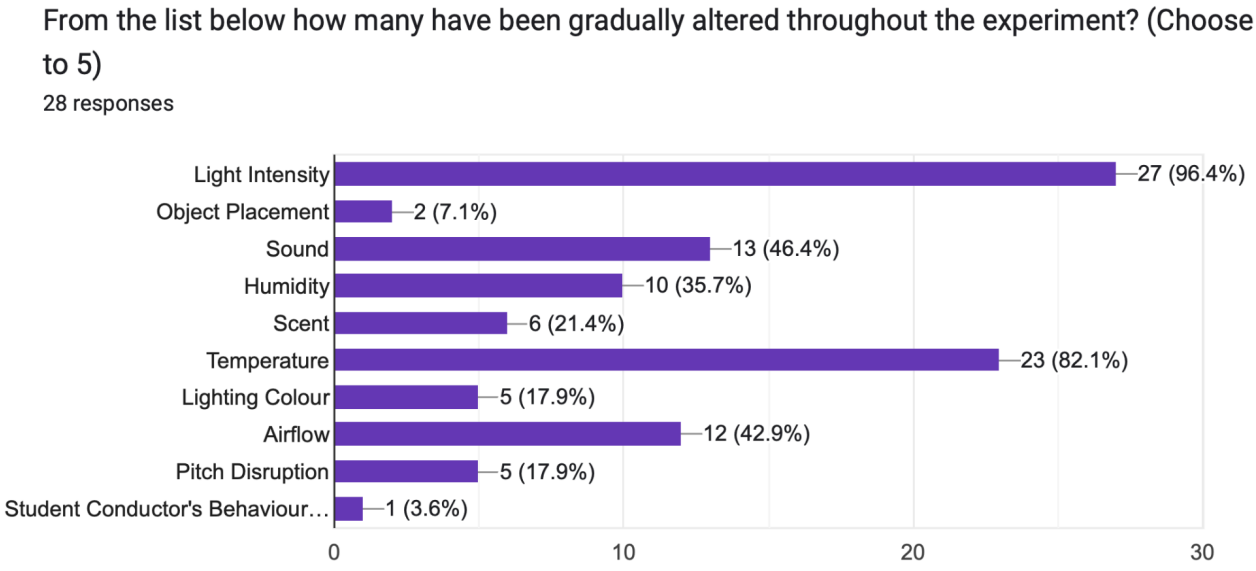
22.5 degrees C. Ending at 23.1 degrees C when it had concluded. Leading to a .6 degree C increase. However, the change in this experiment had been more gradual.

Results of Experiment

We hypothesized that if we change the temperature in a room gradually and over a certain time, then the average person should feel no difference as their thermoreceptors become tolerant. Directly after the experiment, a Google form with seven questions was sent out. Our first question was to determine the percentages of each variable that was changed or was thought to be changed. Participants chose between 10 variables: light intensity, object placement, sound, humidity, scent, temperature, lighting color, airflow, pitch disruption, and student conductor's behavior. Our results displayed that our control group, light intensity, was the most noticed. Proving aspects of our hypothesis, such as nongradual change, has a higher chance of being noticed. The percentage of people who documented this light intensity change is 96.55%. For our gradually changed variables, sound had 46.4% of people who noticed and documented such. Finally, temperature was noticed by 82.1% of participants. As displayed in Fig 1, many variables were also marked as variable changes. In total, only 5 participants found 2-3 of the variables that changed and did not add or subtract other ambient room conditions. Seven participants added or changed one variable from their list. Five participants added or changed two variables. Lastly, 11 participants added or changed three or more variables.

Figure 1

Ambient Room Conditions Noticed by Participants



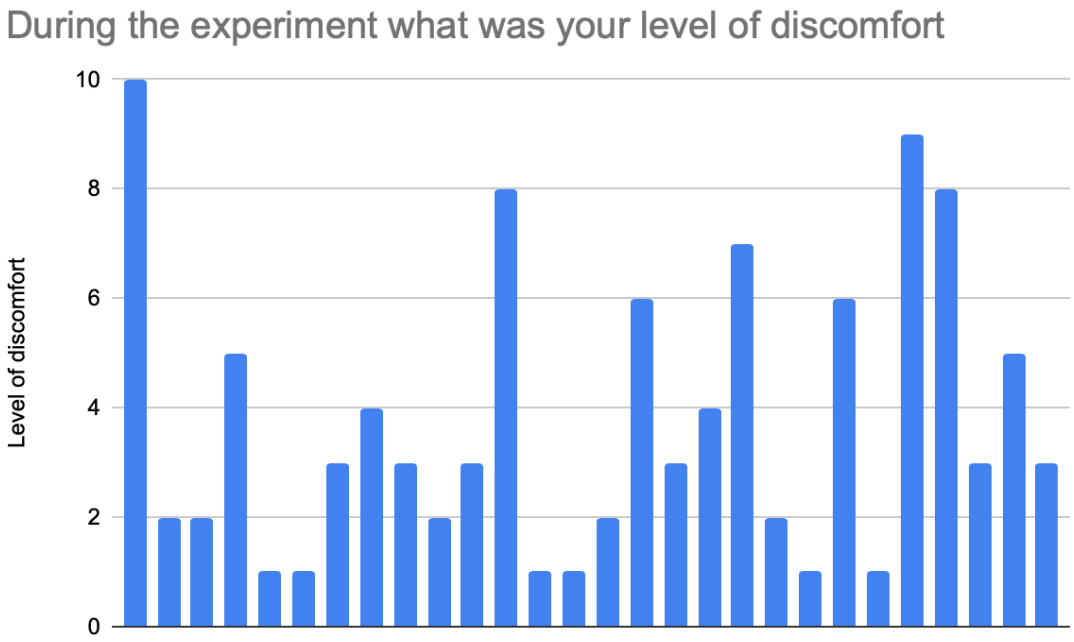
Note. Bar graph of the ambient room conditions noticed by the participants during the experiment. Own work.

Our second question was: During the experiment, what was your level of discomfort? (1-10, 1 being very comfortable, 10 being extremely uncomfortable or unpleasant). Participants answers varied. However, the most common answers were 1 and 3 (Fig 2). This means the participants generally were not affected by the change. About the other questions, we can assume this is because of their adapting to the conditions. Nonetheless, it's obvious that the gradual changes still affected many participants. 9 participants stated their discomfort was a 5 or higher. This also directly correlates with Fig. 3, which displays that 35.5% of participants found it discomforting to work in these conditions. However, as will be discussed in the experimental error, many of these percentages come from the underlying placebo effect and belief in different reality-changing conditions. Our fourth question directly correlated with our third question: At

what point in the experiment were the room conditions most uncomfortable? Many answers stated that the high humidity and flickering lights diverted their attention and caused levels of discomfort. However several other responses stated a change in conditions that had been changed had created discomfort. An example would be scent. A couple of participants noted that the distinct change in smell had caught their attention. As further explained in experimental errors, answers like these show the possible margin of error our experiment may have.

Figure 2

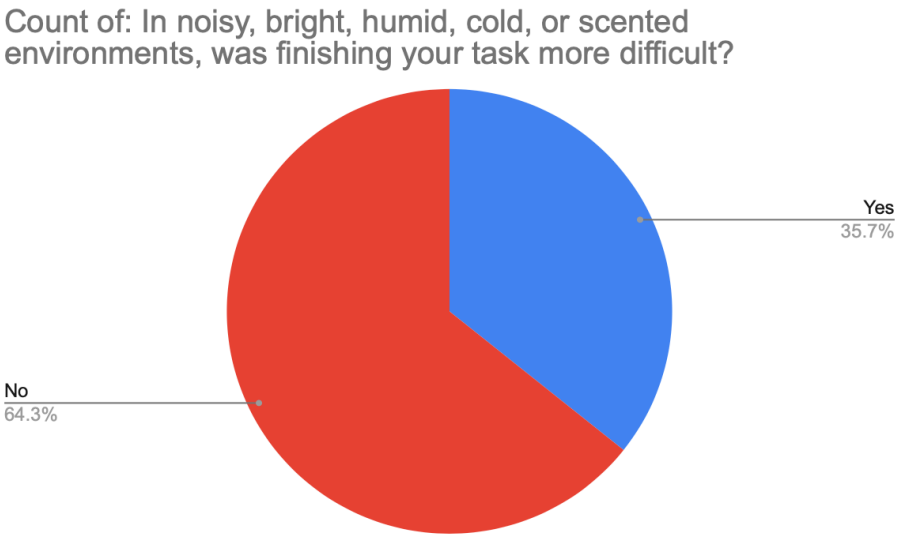
Level of Discomfort Noticed by Participants



Note. Bar graph of the level of discomfort that was noticed by the participants throughout the experiment. Own work.

Figure 3

Difficulty of Task Completion Under Different Conditions



Note. Pie chart of whether participants felt it to be more difficult to complete tasks under noisy, bright, humid, cold, or scented environments. Own work.

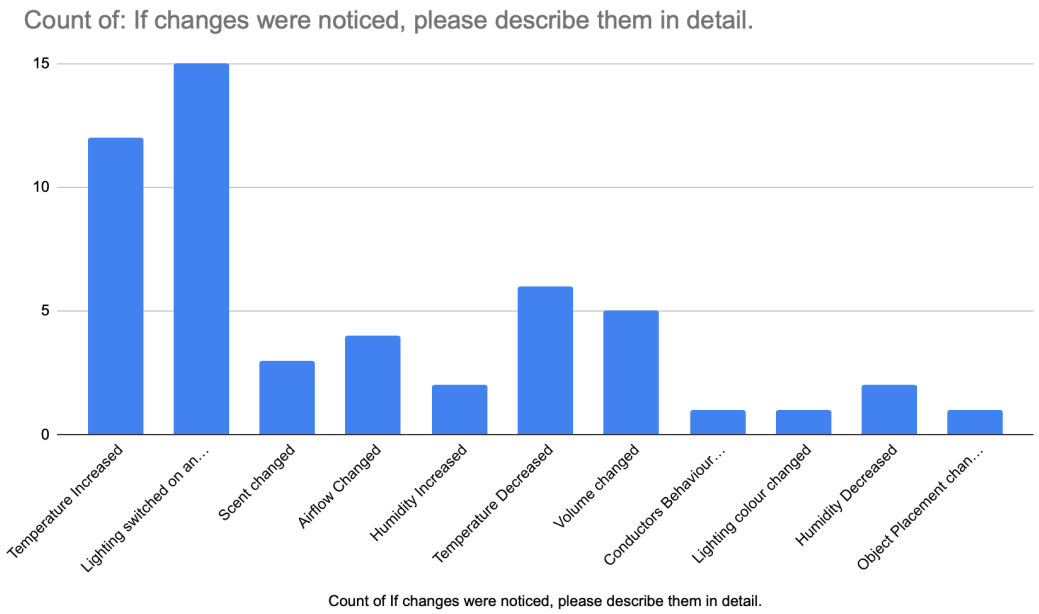
Analysis

We hypothesized that if we change the temperature in a room gradually and over a certain time, then the average person should feel no difference as their thermoreceptors become tolerant. From the information collected, we've concluded that our hypothesis is partially correct. Though many participants noticed the temperature change throughout the experiment, 27.9% did not, as seen in Fig 1. Our supporting point towards the effectiveness of tolerance was proven through the lights. As mentioned before, 96.4% of the participants noticed our lights, a non-gradual change. Therefore, nongradual changes will be felt by society due to thermoreceptors being unable to adapt during direct change. However, the large number of people who had noticed the temperature change implies either one of two circumstances. Our experiment was conducted incorrectly, as discussed in experimental errors. Or people are noticing and refusing to create a change. If our hypothesis is proven incorrect, which is not fully confirmed from just this, this states the effects of global change are being noticed by society on a biological scale. Implying

again that the changes are affecting everybody's body. Our sweating has increased, leading to a noticeable overproduction of acetylcholine. Our veins are vasodilating, limiting their range of motion and effect. And more of the population is suffering from heat strokes, hyperthermia generally, heart attacks, strokes, etc. Our experiment also asked individuals if they perceived a noticeable change during the experiment and how it affected them; this is an extension of the discomfort question. We had answers that were on condition that had not yet been altered. However, many individuals still addressed the temperature. 7 individuals noted the light and linked that directly with impacting their work capabilities. If we wish to apply this in real-life scenarios, we can assume 35% (Fig 3) of individuals are struggling with completing work because of temperature, and though not a sole reason, it is a cause.

Figure 4

Description of Noticed Changes



Note. Bar graph of keywords noticed in the descriptions of the ambient condition changes by participants. Own work.

We also view an interesting static figure in Fig 4. Though over 10 have mentioned an increase in temperature, 7 individuals also mentioned a decrease in temperature. This would indicate our hypothesis is correct; individuals ' bodies are regulated during this 30-minute experiment, allowing the body to feel cooler through various methods. This would mean that, biologically, people are unable to feel the warming of the planet, as their tolerance is restricting their ability to feel a difference. This would also support past reports we've mentioned on current awareness methods being weak, as though we can see a copious amount of graphs in our lifetime. One's body is still unable to feel the change, causing procrastination in fixing this lethal problem. We see other factors like humidity changing. This could either be from a placebo effect or temperature affecting these variables. If participants are noticing a more humid environment, this is most likely from temperature. Resulting in many factors that are neither supporting our hypothesis nor disregarding it. Overall, our hypothesis was not supported by the large number of participants who answered a temperature change. Our hypothesis was supported by the non-gradual change in lights, the noticed decrease in temperature, and potentially the increased humidity.

Experimental Errors

Though this experiment was well-planned and carefully monitored, there are still multiple factors that could have altered the results. First, because many of our participants were close friends with those who knew our experiment's goal, they entered the room with the knowledge that the temperature would change. This may have caused a Placebo Effect, ultimately leading many to feel very warm throughout the experiment. For example, even though on the first day of the experiment, the temperature had only changed by 0.1 degrees Celsius, many participants began to remove items of clothing and comment on how intense the heat of the room was. Such a

reaction should not have occurred with such a low adjustment of temperature. Second, the Hawthorne Effect may have affected the experiment results. Both of the experiment conductors were in the room with the participants. It could be possible that because the volunteers felt like they were being observed or examined, they naturally felt they needed to produce a reaction.

Impact of Project

This experiment extends beyond just exploring tolerance; rather, it has broader implications that impact climate change awareness around the globe. Current methods for awareness are insufficient. The average citizen is aware of climate change as an issue. However, change is stagnant. When activists encourage environmental action, they push images of tragic natural disasters and the millions of lives lost, only to be left confused when society expresses sympathy yet continues to pollute the planet. What needs to be explored further is why no apparent action is being taken. Is it ignorance or a biological incapability to notice there's anything wrong at all? Our experiment hopes to make eco-friendly advertising more effective and bring awareness to humans' natural shift away from the uncomfortable truth of climate change.

Light brightness, a visible distractor, was deemed more noticeable, which demonstrates how in the cases where an increase in temperature is noticeable, visual factors that are even more obvious take priority. Visual changes were considered the most discomforting and evident adjustment. For the same reason, rather than putting in the effort to prevent heat increases, society burns cash and resources to stop wildfires stemming from global warming. Public outcry only occurs when civilians see with their eyes completely preventable tragedies and the consequences that follow them. Communities are stuck in an, "If it can't be seen, it can't be fixed" mindset, the ultimate downfall of climate activism. Although the temperature change was

also noticed during our experiment, this shows that in the status quo, the shift in temperature *should* be noticed, leading to more questions surrounding environmental awareness. Is it purely benightedness and selfish priorities? Is it perhaps the desensitization associated with climate change that makes citizens feel like social movements are just "beating a dead horse?" Our experiment helps explore these questions as well. While the temperature rise was noticed during the experiment, the discomfort it caused wasn't enough to prompt immediate action or understanding of the broader impact.

Additionally, the placebo effect noticed in the experiment demonstrates the effect of misinformation on activism and how one comment could sway an entire room of people toward a certain opinion. The increase in social media use has created another opportunity for civilians to be trapped in echo chambers and gradual radicalization. Heuristics guide users to make impulsive and irrational decisions, leading us to naturally believe false flashy news headlines on the internet. Humans are inclined to follow what feels familiar and what their peers support [36].

These observations offer an insightful perspective into the current education methods framed out earlier and ways they can be improved. First, to combat visual distractors this experiment serves as an accountability measure. By realizing that changes are occurring, we eliminate accidental ignorance that is occurring right now. Our experiment allows for unnoticed stagnancy to come to light and takes out a middleman toward a healthier planet. There is finally a sense of urgency when understanding goes beyond just knowing a problem exists, but rather feeling direct accountability for it. Secondly, to combat social media's effect on climate activism, more regulations on misinformation should be put in place. Although this won't be a perfect solution, showing that there are consequences to actions like account deactivation can limit the spread. Lastly, in regards to desensitization, more work needs to be done on local impactful

change that feels proximate to consumers. This looks like more encouragement to volunteer at national parks so that people can truly see the horror of climate change and the local impacts of global warming rather than the usual distant gory images. Ultimately, our project demonstrates the extent to which current awareness measures fall short and how by investigating the psychological tendencies of consumers, we can create more awareness and effective marketing strategies.

Conclusion

Summary

We hypothesized that if we change the temperature in a room gradually and over a certain time, then the average person should feel no difference as their thermoreceptors become tolerant. We have created this hypothesis for the sole reason of figuring out why humanity was ignorant of a problem as large as global warming. First, Global warming was discussed: why it's happened, how much our atmospheric temperature has changed, and what is causing it. Secondly, we researched many human conditions to perceive temperature. Thermoreceptors, for both hot and cold. Thirdly, our current awareness methods towards children are falling flat. Additionally, it shows how the body tolerates new conditions and changes its resting rate. Finally, past experiments relating to or similar to our experiment were discussed to show this highly discussed topic had been prevalent throughout history. We began conducting our experiment to curate results personally. From our experiment consisting of 28 participants, we've seen many points that supported our hypothesis. However, we've had some that disregarded our points. This could come from experimental errors like the placebo effect, the Hawthorne effect, and general desensitization towards our society. With this experiment, we wish to change these mistakes. Allow society to notice they are not ignorant and that global warming is occurring; however, biologically, humans are not preserving it. This experiment reveals that humanity’s blindness to gradual change isn’t ignorance but rather human psychology. Understanding this limitation gives society power. If individuals can’t instinctively perceive the crisis, then they must force themselves to see it. Global warming is not a distant threat; it is happening now, and governments, companies, and individuals must act before adaptation becomes acceptance.

Acknowledgments

We would like to express our sincere gratitude to all those who supported us throughout the process of conducting and writing this scientific paper. Their guidance and encouragement were invaluable in bringing this project to completion.

First, we would like to thank our teachers for their ongoing support and expertise:

Mx. Dallas, for providing insightful feedback and guiding us as our mentor,

Ms. Paula, for editing and reviewing our writing process.

Dr. Soaras, for offering helpful advice and encouragement during each stage of the research,

Dr. Shahin, whose dedication inspired me throughout this process,

Mrs. Haney, for their patient guidance and assistance with experimental design.

The Renert Science Team, for their encouragement and constructive feedback.

We are also deeply grateful to our parents for their unwavering support and belief in our abilities. Their patience, understanding, and encouragement allowed us to stay motivated and focused on our work.

Finally, we would like to express our appreciation to the judges for their time and consideration in evaluating our paper. Their thoughtful feedback has been invaluable and will guide us in future scientific endeavors.

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